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Interacting Particle Systems and Their Scaling Limits

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The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

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13. ABSTRACT *(Maximum 200 words)*

The primary objective of this project was to understand the long term behavior of interacting systems with a large number of components, especially in the presence of one or more conserved quantities. The basic tool that we used in the analysis was the Dirichlet form. For the model known as the Symmetric Simple Exclusion we established the large deviation principle and in the process of completing the above work we developed an improved existence and uniqueness theory for time inhomogeneous diffusion processes with generators in divergence form involving diffusion coefficients that are degenerate and have only minimal smoothness. We established hydrodynamic limit and large deviation estimates for lattice gas models involving Gibbs measures that satisfy mixing conditions. This is a nongradient system and we had to extend the methods developed earlier for product measures to Gibbs measures with mixing conditions.

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During the grant period we investigated hydrodynamical scaling and related issues for several models and the following results were obtained.

1. For the symmetric simple exclusion process we proved a large deviation principle for the empirical process, which is the random measure with equal weights at the trajectory of every particle. The law of large numbers asserts that this empirical measure converges to the distribution of the tagged particle in equilibrium. We obtain explicitly the rate function for the large deviation principle in terms of the bulk diffusion and the selfdiffusion coefficients of the model. We are currently writing these results up for publication.

2. In the process of proving the above result we needed to improve certain known results on the existence and uniqueness of weak solutions to the heat equation in divergence form, with time dependent coefficients. The diffusion coefficients only had some minimal smoothness and were in addition degenerate. We made these improvements and the results will be written up separately.

3. While we have recently gained considerable understanding of the Green-Kubo diffusion for non-gradient systems, from a technical point of view all the results so far have been for the case when the invariant measures are product measures. We have considered the general case of a lattice gas that has a Gibbs measure with strong mixing properties for its invariant measure. For the natural Kawasaki dynamics in this model we have established the validity of the Green-Kubo diffusion and provided a variational formula for the diffusion coefficient. These results are also being written up for publication.

4. We studied the self diffusion of a tagged particle in asymmetric mean zero simple exclusion model. We established convergence to Brownian motion under the usual rescaling.

5. Dr Sethuraman, another student examined the question of validity of the central limit theorem for additive functionals for different particle systems. In one and two dimensions the correlations decay slowly and the diffusive scaling does not work in general. He was able to establish the precise conditions under which they are valid.

6. Dr Venkatsubramani, another student studied the totally asymmetric simple exclusion model in one dimension. A known results establishes the weak solution of Burgers' equation with the right entropy condition as the limit of the density fields under hydrodynamical scaling. However this needed the initial configuration to be randomly chosen with in a special way. The student's result gets rid of this condition allowing arbitrary initial cofigurations.

7. Mr Alejandro Ramirez, a student who will graduate in 1996 has shown that one dimensional systems possess a mixing property that gaurantees that any week limit of the probability distribution at time t, as $t \to \infty$, is an invariant measure for the system. This simplifies and generalizes a result of Mountford.

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The following articles were published or were submitted for publication based on the results obtained under the support of this grant.

1. Olla, S., Varadhan, S. R. S., and Yau, H. T., Hydrodynamical limit for a Hamiltonian system with weak noise, Comm. Math. Phys. 155 (1993), 523–560.
2. Berestycki, H., Nirenberg,L., and Varadhan, S.R.S., The Principal Eigenvalue for Second-Order Elliptic Operators in General Domains, Comm. Pure Appl. Math. Vol XLVII, 47-92 (1994)
3. Varadhan,S.R.S., Regularity of Self Diffusion Coefficient, The Dynkin Festschrift; Markov Processes and their Applications, Mark I. Freidlin Editor, Birkhauser,(1994) 387-398
4. Varadhan S.R.S., Self Diffusion of a tagged particle in equilibrium for asymmetric mean zero random walk with simple exclusion; Annales De L'I.H.P, Probabilites et Statistiques, Vol. 31, (1995) 273-285.
5. Varadhan S.R.S., Entropy Methods in Hydrodynamic Scaling, Poceedings of ICM, Zurich (1994), 196-208.

The following articles were submitted for publication based on research supported by the grant.

1. The Complex Story of Simple Exclusion, (to appear)
2. Nongradient Models in Hydrodynamic Scaling (to appear)
3. Relative Entropy and Mixing Properties of Interacting Particle Systems (with A. Ramirez, to appear)
4. Spectral gap for Zero-range Dynamics, (With C.Landim and S.Sethuraman, to appear)

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The principal investigator was elected to the National Academy of Sciences as Foreign Associate and was awarded the George D. Birkhoff prize by AMS and SIAM.

The following scientific personnel were supported by the grant.

Short term post doctoral visitors

1. Yuri Kifer
2. Robin Pemantle
3. Timo Seppalainen
4. Fraydoun Rezakhanlou
5. Vladas Sidoravicius
6. Alexandre Mazel
7. Jeremy Quastel
8. Tzong-Yow Lee
9. Stephano Olla
10. Claudio Landim

Graduate Students.

1. Fernando Alegre
2. Ramesh Venakatsubramani
3. Sunder Sethuraman
4. Ali Naddaf
5. Hester Serafini
6. Alejandro Ramirez
7. Ilie Grigorescu

Venkatsubramani, Sethuraman and Naddaf have graduated after receiving their Ph.D. degree.